Relative efficacy of heartwood extracts and proprietory wood preservatives as wood protectants

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Abstract: The relative potentials of either heartwood extracts (air dry extracts in 60 percent methanol) of very durable woods (*Afzelia africana* J.E. Smith; *Erythrophleum suaveolens* (Guill & Perr.) Brenam. Syn. *E guinensis* G.Don. or *Milicia excelsa* (Welw) C.C. Berg. Syn. *Chlorophora* excelsa (Welw) Benth.) or any of two proprietary wood preservatives (AWPA type "C" – Chromated Copper Arsenate (CCA) or 5 percent solution of AWPA Standard Designation P "9" type "C" – Pentanchlorophenol (Penta) in light oil solvent) to suppress attack on pressure treated *Antiaris toxicaria* Lesch Sapwood by either any of three species of decaying fungi (*Coridopsis Polyzona* Klotzch; *Lenzites trabea*: or *Trametes cingulata* Fr.) under soil block exposure conditions were investigated and threshold values determined. Extract/preservative dosages were either 8.009; 24.778; 48.056; 96.111 or 144.167 kg m^{-3} (0.5; 1.5; 3.0; 6.0 or 9.0 1b/ft^3). Exposure was for either 14 or 28 weeks and in accordance with ASTM D1413 – 72 Provisions. Conclusions reached were that at threshold values the ability of either any of the heartwood extracts or proprietary wood preservatives to suppress attack under conditions in this study was significant at 0.01. Relative efficacy of those biocides was dependent on fungal species. Neither any of the heartwood extracts nor any of the proprietary wood preservatives (except in the case of *Trametes cingulata* attack on CCA treated wood at highest retention level) was able to confer "very durable" rating on treated wood. Possible reasons for the reduced relative durability of extracts visa vis native heartwood were advanced. At the highest retention level (144.167 kg m^{-3}) there was no significant difference (at 0.05 level) between efficacy of each of the heartwood extracts and any of the proprietary wood preservatives (CCA or Penta).

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Introduction

Experts are in agreement that most conventional proprietory commercial wood preservatives pose great threat to the health of wood treatment workers, endanger the safety of users and posses latent capacity to degrade the quality of the environment (Fisher 1968; Thompson 1971; Coggins and Moldrup 1991; Barnes and Nicholas 1992; Barnes and Murphy 1995; Borazjani *et. al.* 1997; Onuorah 2000). Available records indicate that most efficient disposals and detoxification methods of the above group of preservatives are either expensive or time consuming depending on the choice of methods employed (Fisher 1968; Thompson and Dust 1971, 1972a, 1972b, 1973; Coggins and Moldrup 1991; Borazjani *et al.* 1990). Researchers have made considerable efforts in search of alternative preservative chemicals that will not only match the efficacy of most valued traditional wood preservatives but shall at same time have reduced mammalian and ecotoxicity and be generally cost effective (Nicholas 1983; Bultman *et. al.* 1991; Barnes and Murphy 1995; Onuorah 2000).

Authorities on wood biodegradability are in agreement that the heartwoods of some Nigerian timber species posses varying levels of natural durability (Princess Risborough Laboratory 1963, 1972; Ifebueme 1977; Findlay 1985). The natural durability of heartwoods has been ascribed mainly to the presence of heartwood extractives (Rudman 1962; Ifebueme 1977; Schultz *et. al.* 1995). The active chemical constituents of the extractives associated with the heartwoods of some Nigerian hardwood timber producing species have been isolated and characterized. A compendium on reported characteristics of these groups of heartwood extractives can be found in Ifebueme (1977), while the ability of some of these extractives to impart natural durability to their native timber species have been widely accepted, very little has been known and reported of their efficacy when extracted and used in the protection of another perishable timber species. If the relative efficacy of heartwood extracts when compared to that of conventional proprietary wood preservatives are known and the threshold dosages for each type established, then the groundwork for the development of more environmentally friendly and safer to use biocides would have been laid since the latter group, being product of nature, may be easier to detoxify through the normal biological processes.

The aims and objectives of this study were:(1) To determine the relative efficacy of extracts from heartwoods of very durable tropical hardwood timber species and that of two different conventional proprietary commercial wood preservatives (penta and CCA) in suppressing attack on treated sapwood of *Antiaris toxicaria* Lesch (a perishable but permeable tropical hardwood timber species) by eachof

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three species of fungi (namely, *Lenzites trabea*; *Coridopsis polyzona* Klotzch and *Tremetes cingulata* Fr.); and (2) To determine the threshold value for each of the heartwood extracts and for each of the conventional proprietory wood preservatives.

Materials and methods

Study sites

All tropical hardwood species used for this study were harvested within the area defined by the geographical co-ordinates of 4º42"-9º02" N and 4º20"-8º55" E (Agboola 1979). Rainfall within the area is bimodal (a high of 7–8 months of rainy season in the Southern part of the Zone to a low of 5–7 months in the more Northern part of the Zone). The vegetation cover ranges from the tropical rainforest in the South through derived Savanna to Guinea Savanna in the North. Many tropical rainforests had been degraded through intensive agriculture although relics of the old forest exist in parts. Within the Southern Guinea savanna there are riparian forests in river valleys and low-lying lands. Mean annual rainfall for the area ranges from a low of 1 350 mm in the North to a high of 2 250 mm in the south. The mean annual temperature is about 27ºC while the relative humidity (R.H.) ranges from a low of about 24% during dry harmattan months to a high of 90% at the peak of the rainy season.

Preparation of extracts

The procedure used for the extraction of heartwood extractives was as previously reported by same author (Onuorah 2000). Three representative trees were randomly selected at different locations typical of known ecological and vegetation spread of each species. Each tree was subsequently felled and representative sample discs cut at the three different points along the free bole. The wood of each timber species was identified in the laboratory using the procedure reported by Brazier and Franklin (1961). Growth ring count indicated that the ages of the trees ranged from 35 to 78 years. Sapwood was separated from heartwood after the method reported by Okoro (1982). The heartwood of each species was wiley milled to a 20 mesh size and soxhlex extraction done separately using methanol at room temperature for ten days (Kamden 1994). The strength of methanol used was 60%. Another material used was an extraction thimble of defatted paper. The solvent was made to pass through the Wiley milled wood dust at a rate of five times an hour. The extract was filtered in glass funnel fitted with glass wool and the funnel and flask rinsed with small quantity (about 30 ml) of fresh methanol. The extract solution was finally evaporated to constant weight in a vacuum oven at approximately 50±2°C.

Proprietary wood preservatives

Two types of conventional proprietary wood preservatives were used namely Chromated Copper Arsenate (CCA) and pentachlorophenol (penta).

The CCA conformed to American Wood Preservers' Association (AWPA) standard type "C" and has the following relative oxide per-centages in its composition CrO_3= 46%; CuO= 20% and As_2O_5 =34%. The preservative was used as a salt free liquid concentrate containing 50% preservative on an oxide basis. Conversely, the pentachlorophenol (penta) used in this study conform to AWPA standard and Designation P "9" type "C" (light oil carrier). It has 5 per cent of penta in solution.

Impregnation of timber

Antiaris toxicaria Lesch Syn. *A. africana* Engl., a commercial hardwood timber species widely distributed in the rainforest belt of Central, Eastern and Western Africa, was chosen for the study. Although this timber is widely available, its efficient utilization is hampered by its propensity to be prone to all forms of biodegradation. It is thus classified as perishabvle but fortunately it is also rated as permeable to wood preservative treatment (Princess Risborough laboratory 1963, 1972; Ifebueme 1977). Sawn boards of this species were received from the saw miller at the green chain. Sapwood was separated from heartwood after the method reported by Okoro (1982). The *A. toxicaria* lumber was, after air-drying for four weeks, reduced to 1.5 cm by 2.5 cm by 5.0 cm specimen blocks. Thirty specimen blocks obtained from sapwood region only were either vacuum impregnated with either each of the three heartwood extracts or any of the two conventional proprietary wood preservatives at a pressure level to ensure desired dosage which had been previously determined from preliminary trials. Thus the total number of specimens impregnated with either heartwood extracts or proprietary wood preservatives was 750 (i.e. 5 blocks by 6 different exposure conditions (3 different species of fungi by two different durations of exposure) by 5 different heartwood extracts/preservatives by 5 different retention levels). Another set of thirty matched samples randomly selected were untreated and used as control. In other words, five specimens were tested for each treatment and exposure combinations.

This brought the total number of specimens used for the test to 780 specimens. Treated samples and control were later air-seasoned in the open laboratory for four weeks to enable them acquire Equilibrium Moisture Content (EMC). At the end of this period, all specimens were weighed using electrically sensitive balance and the weight of each specimen recorded.

Exposure conditions

Treated blocks and control were later exposed to three different species of decayed fungi, (*Lenzites trabea*; *Coridopsis polyzona* Klotzch; and *Trametes cingulata* Fr.); in soil block test according to the procedure set out by ASTM D1413-72 except that the blocks were never leached. *Coridopsis polyzona* Klotzch and *Trametes cingulata* Fr. were used in this study because both are major causes of

decay of timber in Service in the West African sub-region (Ofosu-Asiedu 1975; Odeyinde 1977).

After 14 weeks exposure, half the total number of specimens for each retention level (treatment) /fungus combination were removed from the test bottles and mycelium were carefully brushed off the samples. These sets of specimens were then allowed to air-dry in the open laboratory for four weeks. At the end of this period, each specimen was reweighed and the weight recorded. The rest of the unremoved specimens (390 Nos.) were allowed to continue with the test until at the end of 28 weeks after which the test was discontinued and the process described above was repeated. Weight loss was defined as the difference between the weight before and after fungal exposure was terminated.

Assessment of test results

A student t-test was used to test for level of significant difference between means of the various treatments. Simple descriptive statistics was also used to make relative comparisons of the efficacy of the various heartwood extracts/proprietary wood preservatives vis-à-vis results obtained from attack on control specimens. The durability rating adopted by Findlay (1985) was used in ascribing efficacy. Under this system, a weight loss above 30% means that the wood is "perishable", 10-30% weight loss means that the wood is non-durable 5-10% means that the wood is "moderately durable; up to 5% weight loss means "durable" while nil or negligible per-cent weight loss means that the wood is rated as very durable. Thus, for treatment to be considered and accepted as efficacious, the-treated-wood must not only have achieved a reduced weight loss that is significantly different from the mean per-cent weight loss recorded for the control under same exposure conditions but must additionally not record a weight loss above what is needed to confer a durability rating of "moderately durable". In other wards, a weight loss above 10 per cent for any treated wood, is accepted as implying that the very particular treatment is not suitable as a wood preservative at the dosage level used.

The threshold value was fixed as that retention level at which no significant reduction in weight loss was recorded between-weight loss recorded after 14 weeks and at end of 28 weeks exposure. Such retention value must additionally confer at least a weight loss not more than what is required to confer 'moderately durable" rating using the Findlay (1985) classification.

Results and discussions

The results showing the relative weight loss of wood treated with different chemicals and at different retention levels used in this study are presented in Table 1. The threshold retention levels for either each of the heartwood extracts or each of the proprietary wood preservatives are presented for each treatment combinations in Table 2. In analyzing the results, three mutually dependent criteria were evolved:

(1) That the reduction in mean weight loss of treated specimens when compared relative to the mean weight loss of untreated specimens (control) at same exposure conditions achieved at least 5% level of significant difference as adjudged from student t-test (Loftus and Loftus 1988).

(2) That the average weight loss for the particular exposure and treatment combination was able to achieve a weight loss reduction not higher than would otherwise give same the equivalent of durability rating of "moderately durable" which according to Findlay (1985) is within the range of 5% to 10% weight loss.

(3) To define and determine the threshold value which in this case is defined as the minimum amount of preservative that is effective in preventing decay under test conditions (ASTM D1413-72). This is further defined as that extract/preservative dosage level which gives a weight loss equivalent to that required to earn a rating of "moderate durability" based on level of weight loss due to fungal attack and at same time not record any significant difference between the mean weight loss recorded at the expiration of the 14 weeks test and those recorded at the expiration of 28 weeks exposure.

The above definition of threshold appears more stringent than the broad definition of threshold given by either AWPA standard M 10-63 or ASTM D 1413-61. Behr (1973) noted that definition of threshold by professionals in the field has been very broad and that one needs to read what the worker provided in order to put meaning on reported threshold values.

A close look at Table 1 and Fig.1 through 3 will reveal that the tolerance level for each fungus varied depending on the treatment chemical (Heartwood extract/proprietory wood preservative) and that for each heartwood extract or proprietory wood preservative, the tolerance level varied depending on the species of fungus. Both findings are in agreement with conclusions reached by other workers (Zebel 1954; Cowling 1957; Nicholas and Schultz 1997). Critical study of Table 1 will also reveal, that based on the weight loss recorded, none of the heartwood extracts used for this study was able to confer a protection enough to give the treated wood a durability rating of "very durable". Since the heartwood of each of the species whose extracts was used for this study is classified and ranked as "very durable", some explanation is required here. One explanation is that the interplay of the host wood species used in the test played a role in modifying the relative efficacy of the extracts. The other is in keeping with the findings of Duncan (1958) who concluded that the species of wood influences the threshold for wood preservative fungus combination. Yet, a third explanation is that higher dosage level may be necessary to achieve same durability rating as the native heartwood from which extracts was obtained.

Table 1. Mean weight loss of *Antiaris toxicaria* lesch sapwood pressure treated with either heartwood extract of very durable tropical hardwood species or with proprietary wood preservatives after either 14 weeks or 28 weeks exposure to fungal attack in soil block test**

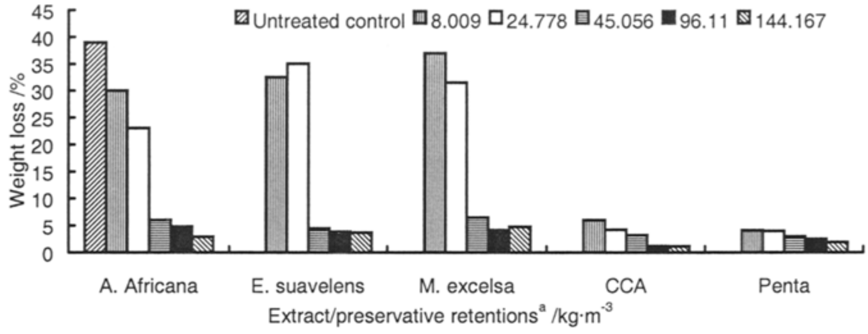
Source of heartwood extracts/wood preservative	Retention level / kg· m^{-3}	Percentage weight loss *					
		Lenzites trabea		*Coridopsis polyzona* Klotzch		*Trame-tes cingu-lata* Fr.	
		14 (Weeks)	28 (Weeks)	14 (Weeks)	28 (Weeks)	14 (Weeks)	28 (Weeks)
Afzelia africana J.E. Smith	8.009	30.01A	36.04A	35.0A	39.00A	34.90A	37.50A
	24.778	23.03B	27.02B	25.31B	26.00B	28.00B	30.03A
	48.056	6.00C	7.01C	19.80B	24.90B	9.01C	5.69C
	96.111	4.81D	5.31C	5.80C	3.98D	5.00C	4.15D
	144.167	2.90D	4.02D	6.10C	4. 65D	3.61D	4.64D
Erythrophleum Suaveolens (Guill & Perr.) Brenan Syn. *Erythrophleum guinensis* G. Don.	8.009	32.50A	41.00A	34.01A	38.00A	37.06A	41.02A
	24.778	35.03A	37.51A	34.80A	36.61A	30.11A	36.61A
	48.056	4.50D	9.42C	25.67B	30.83A	27.05B	29.81B
	96.111	3.92D	4.05D	4.90D	5.03C	4.81D	3.96D
	144.167	3.72D	3.81D	4.50D	3.92D	3.67D	3.03D
Milicia excelsa (Welw) C.C. Berg. Syn. *Chlorophora excelsa* (Welv,) Benth.	8.009	37.02A	43.03A	41.01A	44.22A	39.01A	43.04A
	24.778	31.51A	38.02A	28.05B	30.70A	34.06A	40.08A
	48.056	6.50C	7.8 C	19.68B	23.16B	18.62B	28.14B
	96.111	4.20D	4.15D	5.14C	8.81C	10.81B	17.91B
	144.167	4.80D	1.76D	4.02D	4.15D	3.27D	3.49D
Chromated Copper Arsenate (CCA)	8.009	6.01C	7.11C	12.11B	21.05B	25.66B	29.03B
	24.778	4.25D	3.82D	8.02C	9.04C	7.92C	8.96C
	48.056	3.22D	3.43D	5.16C	7.80C	1.47E	4.89D
	96.111	4.17D	2.05D	3.65D	4.15D	2.01D	2.81D
	144.167	1.15E	1.87D	2.23D	3.24D	0.87E	1.25E
Pentachorophenol (Penta)	8.009	4.12D	4.15D	16.03B	20.61B	4.03D	4.71D
	24.778	4.00D	4.12D	3.11D	4.99D	3.67D	3.95D
	48.056	3.00D	3.31D	2.98D	3.00D	3.13D	4.01D
	96.111	2.50D	2.61D	2.45D	2.84D	2.78D	3.00D
	144.167	1.90D	1.89D	1.87D	2 15D	2.51D	2.66D
Control[a]	-	39.00A	43.10A	34.07A	40.11A	36.03A	45.12A

Legend: a = Untreated representative matched samples of *Antiaris toxicaria* Lesch sapwood randomly selected and exposed to same test conditions as treated specimens.
* = Percentage weight losses not accompanied by same alphabets are significantly different one from another at 5 percent level.
** = Weighted averages based on five specimens per test.
Note: A = Perishable = Over 30 percent weight loss after 28 weeks exposure
B = Non-durable = 10 to 30 percent weight loss after 28 weeks exposure
C = Moderately durable = 5 to 10 percent weight loss after 28 weeks exposure
D = Durable = 1.5 to 5 percent weight loss after 28 weeks exposure
E = Very Durable = 1.50 percent weight loss or less after 28 weeks exposure

It is also significant to note that only CCA achieved a rating, as adjudged from the weight loss recorded (see Table1), that confers a raking equivalent of "very durable" on treated wood and that this rating was only achieved when wood treated with the highest dosage level used for the study (144.167 kg m^{-3}) was used in suppressing attack from *Trametes cinqulata* Fr. The other proprietary wood preservatives, penta, achieved significant reductions at all concentration (see Table 1 and Fig.1 to 3) and exposure conditions used in this study but never conferred a durability rating higher than "durable" on the treated wood. Following the above trend, one can conclude that in general the heartwood extracts when used at retentions of 144.167 kg m^{-3} and above achieved same level of efficacy, as adjudged from weight loss reduction, in suppressing attack on treated wood as the proprietary wood preservatives. Specific trends as it relates to each fungus is discussed hereunder.

Lenzites trabea

The relative mean weight loss due to attack of *Lenzites trabea* on wood treated with either each of the heartwood extracts or each of the proprietary wood preservatives after either 14 weeks or 28 weeks exposure are presented in Fig.1A, and Fig.1B respectively. It could be seen from Fig.1A that each of the extracts achieved significant reduction in weight loss at heartwood extract dosage levels of 48.056 kg m^{-3} during the 14 weeks test period. Conversely both the CCA and penta used in this study were both efficacious in preventing attack at the lowest retention level used in this study (8.009 kg· m^{-3}).



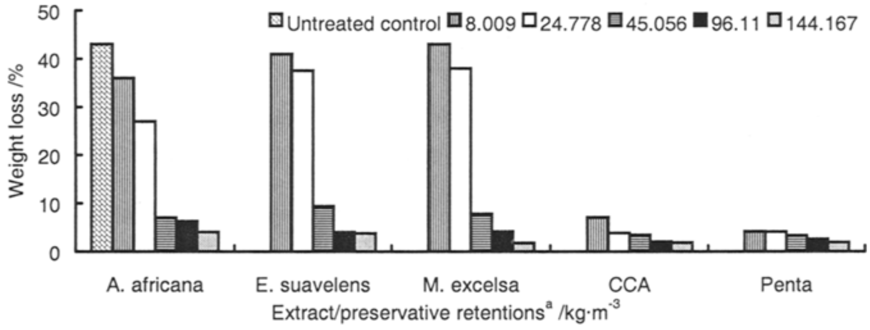


Fig.1 Relative average weight loss of *Antiaris toxicaris* sapwood pressure treated with either heartwood extracts or proprietary wood preservatives to *Lenzites trebea* in soil block test

A: after 14 weeks exposure; B: after 28 weeks exposure

Note: a= Retentions expressed on dry salt or extract basis retained by the treated; Reference to species under neath the bar charts relate to the heart extract

Following the earlier set criteria therefore, the threshold values required for the various extracts used in this studies to effectively suppress attack of *L. trabea* is 48.056 kg m^{-3} while the threshold value for CCA treated wood is 8.009 kg m^{-3} and ≤ 8.009 kg m^{-3} for penta treated wood (see Table 2). Note that at the highest retention level used in this study (144.167 kg m^{-3}) there is no significant difference in weight loss recorded for wood treated with either each of the heartwood extracts or those treated with any of the two proprietary wood preservatives. The implication of this is that each of these extracts or proprietary wood preservatives could extend the service life of a perishable wood species to about 15 to 25 years (Princess Rishorough Laboratory 1972).

Table 2. Relative threshold values* of either heartwood extracts of very durable tropical hardwood species or proprietary commercial wood preservatives used in pressure treatment of *Antiaris toxicaria*_lesch sapwood and exposed to fungal attack for 28 weeks in soil block tests

A source of heartwood extracts/ type of proprietary wood preservatives	Threshold dosage /kg· m^{-3}		
	Lenzites trabea	*Coridopsis polyzona* Klotzch	*Trametes cingulata* Fr.
Afzelia africana L.E. Smith	4.056	96.111	48.056
Erythrophleum suaveolens (Guill & Perr.) Brenan Syn. *Erythrophlem guinensis* G.Don	48.056	96. 111	96.111
Milicia excelsa (Wlew.) C.C. Berg. Syn. *Chlorophora excelsa* (Welw) Benth.	48.056	96.111	144.16
Chromated Copper Arsenate (CCA)^{K}	8.009	24.778	24.778
Pentachlorophenol (Penta)^{a}	8.009	24.778	8.009

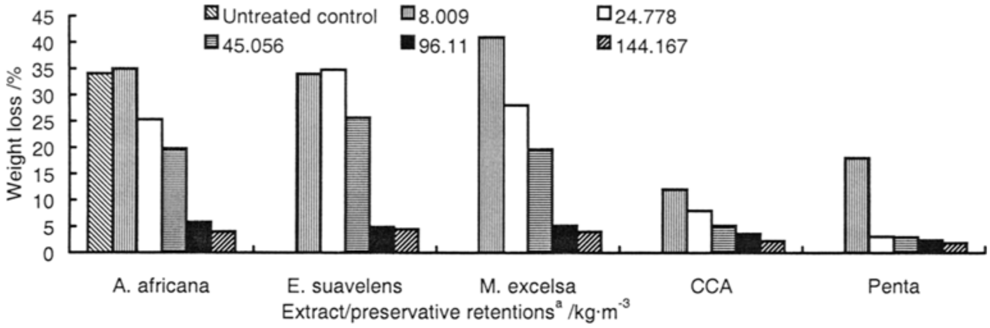
Legend: *= Minimum heartwood Extract/Wood preservative retention in treated wood that upon fungal exposure significantly suppresses attack and reduced weight loss of the treated wood to 10 percent or less.

K = AWPA standard type "C" composed of 50 percent preservative on oxide basis

a = AWPA standard designation D p'9 ' type "C" in light oil carrier and has 5 percent penta in solution.

Coridopsis polyzona klotzch

Fig.2A and B show the relative efficacies of the various extracts and proprietary wood preservatives used in this study in suppressing attack due to *C. ployzona* on treated wood after either 14 weeks or 28 weeks exposures. In general, this species of fungus appears of more tolerant of both the heartwood extracts and the proprietary wood preservatives used in this study as higher chemical retention levels were required to prove efficacy when compared relative to *Lenzites trabea* (Table 1 and 2). In general, each of the heartwood extracts required extract retention levels of 96.11 kg· m^{-3} to reach the threshold value (Table 2). This species of fungus is also more tolerant of each of the proprietary wood preservatives, when compared relative to *L. trabea*, as in all cases the higher preservative retention (24.778 kg m^{-3}) was required to reach the threshold value (see Table 2). Contrary to observed trend with respect to attack on treated wood, penta performed better in suppressing attack on treated wood at all preservative retention levels when compared relative to CCA. It is however important to note that at the highest dosage level of 144.167 kg m^{-3} used in this study, there is no significant difference (at 0.05 level) between the efficacy of each of the heartwood extracts and that of each of the conventional proprietary wood preservatives.



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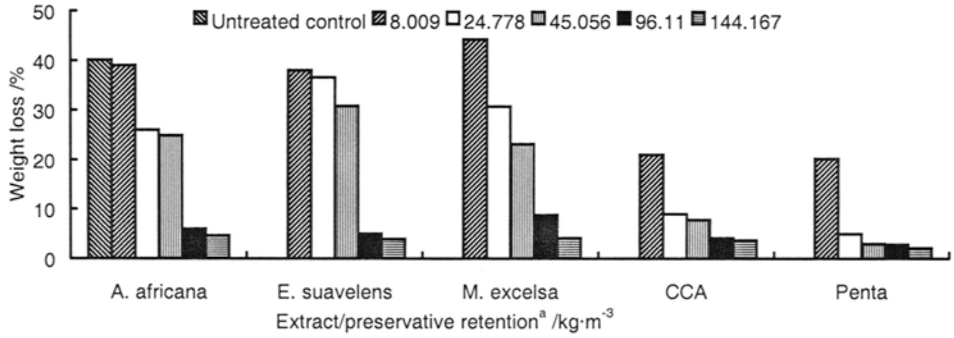


B

Fig.2 Relative average weight loss of *Antiaris toxicaria* sapwood pressure treated with either heartwood extracts or proprietary wood preservatives to *Coridopsis polyzona* klotzch in soil block test

A: after 14 weeks exposure; B: after 28 weeks exposure

Note: a= Retentions expressed on dry salt or extract basis retained by the treated; Reference to species under neath the bar charts relate to the heart extract

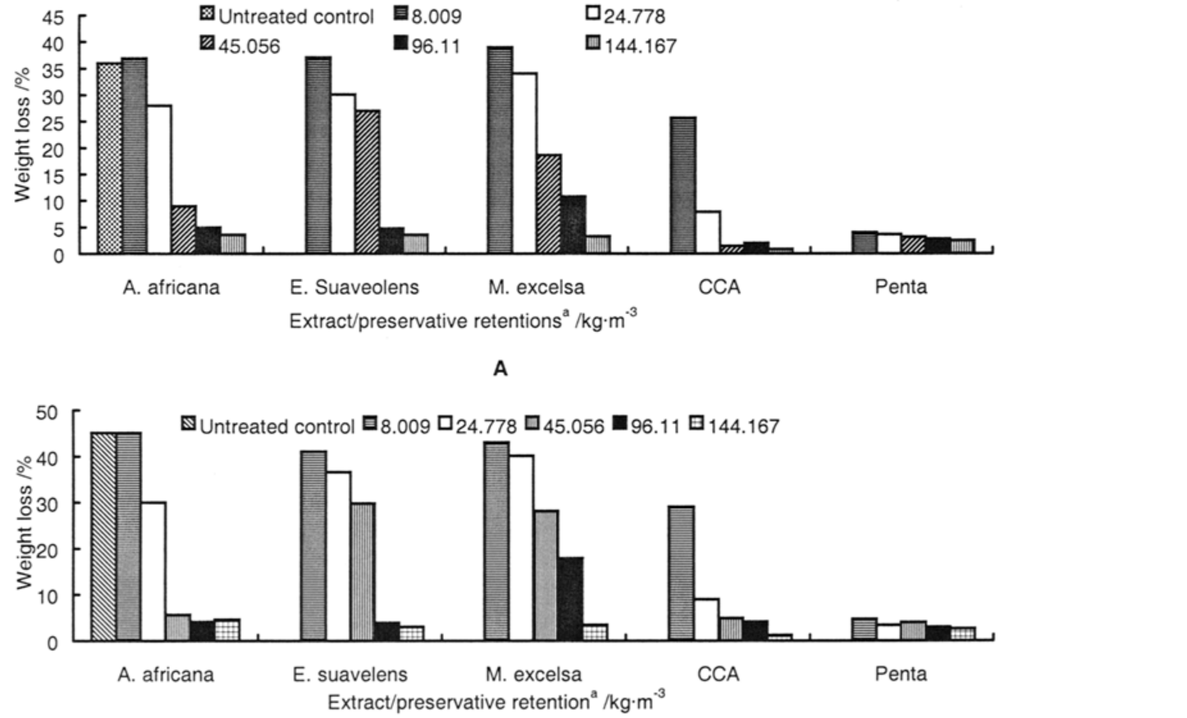
Trametes cingulata fr.

The relative efficacies of either each of the heartwood extracts or each of the proprietary wood preservatives in suppressing attack on treated wood by *T. Cingulata* Fr. are captioned in Fig.3A and Fig.3B for the 14 weeks and 28 weeks exposures. The threshold values for either each of he heartwood extracts or for each of the proprietary wood preservatives are presented in Table 2.

It could be seen from Table 2 that in the case of wood treated with the various heartwood extracts, the dosage level required to achieve the threshold value varied as the source of extract varied. Thus the lowest threshold value (48.056 kg m^{-3}) was obtained for wood treated with heartwood extracts of *Afzelia africana* J,E. smith while the threshold value in case of extracts obtained from heartwood extracts of *Milicia excelsa* (welw.) C.C. Berg syb. *C. excelsa* (welw.) Benth could only be achieved at the highest retention level (144.167 kg m^{-3}) used in this study (Table 2).

The threshold values were much lower for the proprietary wood preservatives when compared relative to those of heartwood extracts. Penta gave the lowest threshold value at 8.009 kg m^{-3} preservative retention while CCA only achieved the threshold value at preservative retention of 24.056 kg m^{-3}. However, at the highest dosage level used in this study. CCA proved superior to each of the heartwood extracts and even penta since it succeeded in conferring a rating equivalent to "very durable" on the treated wood

judging from the negligible weight loss (see Table 1). The difference between efficacies of CCA treated wood and other treatments (either penta or any of the heartwood extracts) at the highest retention level were found significant at 0.05 level. Each of the extracts conferred same level of durability rating as penta at the highest chemical retention level used in this study (Table 1).



B

Fig.3 Relative average weight loss of *Antiaris toxicaria* sapwood pressure treated with either heartwood extracts or proprietary wood preservatives to *Trametes cingulata* in soil block test

A: after 14 weeks exposure; B: after 28 weeks exposure

Note: a= Retentions expressed on dry salt or extract basis retained by the treated; Reference to species under neath the bar charts relate to the heart extract

Conclusions and recommendation

Based on the results and analysis of results obtained from this study the following conclusions and recommendations can be made:

Each of the heartwood extracts (*A. africana*; *E. suavelens*; and *M. excelsa*) and each of the proprietory wood preservatives (CCA and penta) proved efficacious in suppressing attack on treated wood by any of the species of fungi used in this study (*Lenzites trabea, Coridopsis polyzona* kloctzch and *Trametes cinqulata* Fr.)

For each heartwood extract or proprietary wood preservatives; the ability of the fungus to tolerate varying levels of chemical retention depends on the species of fungus responsible for biodegradation.

Although each of the extracts (at the highest dosage level used) was able to suppress attack on treated wood and to confer a durability rating of "Durable" (Findlay 1985) on an otherwise perishable sapwood, each failed to confer the highest rating of "very durable" which is the rating for the heartwood of each of the species from which the extracts used were obtained. This leaves one to conclude that there are some genetic threats that enhance the potency of the extracts or that the solvent failed to remove all active ingredients that give potency to the extracts. It may also mean that higher dosages/retention levels may be required to achieve par with the native heartwood from which the extract was obtained.

Judging from the threshold values, *L. trabea* appears to be more sensitive to either any of the extracts, penta or CCA than either *C. polyzana* or *T. cingulata.*

At the highest retention level (144.167kg/m^3) used in this study there was no significant difference (at 0.05 level) between the ability of any of the extracts used in this study and pentachlorophenol (5% AWPA D P '9' type C – light oil solvent carrier). However, CCA when used at the highest dosage level for suppression of *T. cingulata* attack proved effective at this retention level than any of the extracts or even penta. This was significant at 0.05 levels.

Field studies are therefore recommended to help determine efficacy in service since efficacy has been proven in the laboratory. This is because since each of the extracts was able to give a durability rating/ranking of "Durable"; based on weight loss (Findlay, 1985) service records is required to make sure that this also conforms with the ex-

pected life of 15 to 25 years which is the expected life of a naturally "durable" wood (Princess Risborough laboratory 1972).

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